JACOBS SVERDRUP

INTEGRATED PROJECT MANAGEMENT:

A Case Study in Integrating Cost, Schedule, Technical, & Risk Areas

Greg Smith, EVM/Schedule Specialist

Jacobs Sverdrup, Project Management Team

email: james.g.smith@msfc.nasa.gov phone: (256) 544-3195

INTEGRATED PROJECT MANAGEMENT

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- BACKGROUND
- GETTING STARTED
- DEVELOPING THE PLAN
- DIVERGING PATHS (REALLY?)
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- CONVERGING PATHS
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  - ESTABLISHING THE BASELINE
- IT ALL COMES TOGETHER
- LESSONS LEARNED

OBJECTIVES

- ❑ To demonstrate the practical application of good integrated project management principles to a real project
- ❑ To endorse those project management principles that support a successfully managed effort
- ❑ To share the pain and rewards of discovery with others so that they may avoid the pain and embrace the rewards

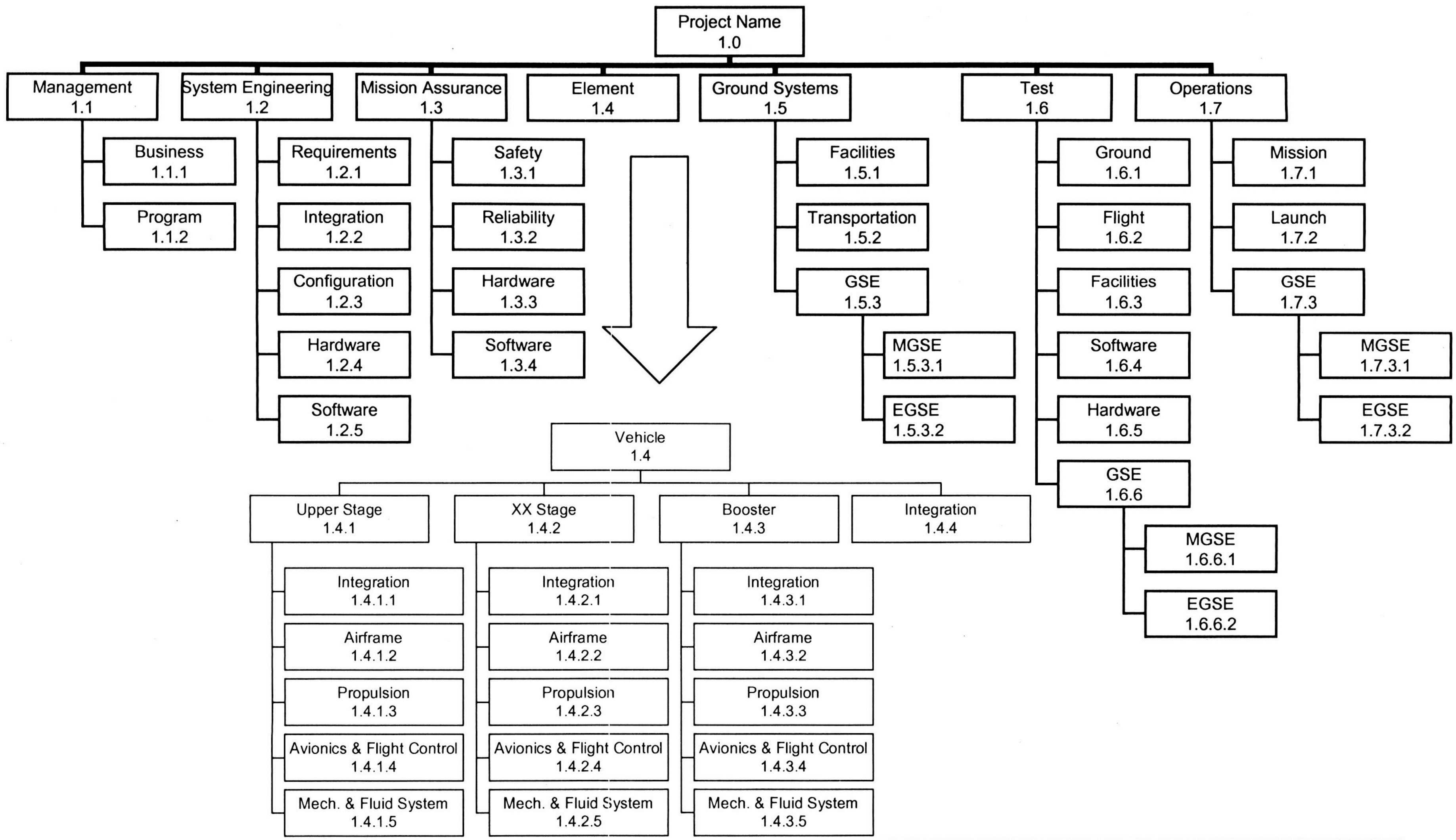
CASE STUDY BACKGROUND

- The International Space Station (ISS) fluid filtration system uses disposable cartridges
- These cartridges were procured from a contractor who developed the fluid filtration system
- The contractor "lost" the cartridge technology and could no longer provide off-the-shelf replacements
- The contractor offered to "re-design" and fabricate the replacement cartridges for a cost
- The ISS Program Office (ISSPO) decided to pursue developing the cartridges "in-house"

GETTING STARTED

- A need was identified
  - Replacement cartridges for ISS fluid filtration system
- Expectations were conveyed – at a high level
  - Time Frame = X years
  - Budget = $X M
- The project team was formed
  - Work scope was discussed – the conceptual plan was developed
  - Preliminary roles were defined - an informal OBS was developed
- Detailed planning began
  - A WBS template was obtained with a product-orientated structure
  - The template was modified by the project team to suit the project

EXAMPLE OF WBS TEMPLATE



EXAMPLE OF MODIFIED WBS (1 OF 2)

- Gas Trap Insert 1.0
  - Management 1.1
    - ISSPO 1.1.1
    - Project Management 1.1.2
    - Project Controls 1.1.3
  - Systems Engineering & Integration 1.2
    - Specifications 1.2.1
      - Interfaces 1.2.1.1
      - Requirements 1.2.1.2
    - Conceptual Design 1.2.2
    - Component & Systems Integration 1.2.3
    - Configration & Data Management 1.2.4
      - CM 1.2.4.1
      - DM 1.2.4.2
    - Verification 1.2.5
  - Safety & Mission Assurance 1.3
    - Safety 1.3.1
    - Reliability 1.3.2
    - Quality 1.3.3
  - Gas Trap Hardware 1.4
    - Hydrophilic Membrane 1.4.1
    - Hydrophobic Membrane 1.4.2
    - End Caps 1.4.3
    - End Plates 1.4.4
    - O-Rings 1.4.5
    - Stiffener 1.4.6
    - Glue 1.4.7
    - Hardware Assembly 1.4.8
  - Ground Systems 1.5
    - Facilities 1.5.1
    - Transportation 1.5.2
    - GSE 1.5.3
      - MGSE 1.5.3.1
      - EGSE 1.5.3.2
  - Testing & Evaluation 1.6
    - Qualification 1.6.1
    - Acceptance 1.6.2
    - Fleet Leader 1.6.3
      - Contamination 1.6.3.1
      - Gas Removal 1.6.3.2
  - Sustaining Engineering 1.7

EXAMPLE OF MODIFIED WBS (2 OF 2)

- **Gas Trap Hardware 1.4**
  - Hydrophilic Membrane 1.4.1
    - Design & Analysis 1.4.1.1
    - Procure 1.4.1.2
    - Manufacture 1.4.1.3
    - Test 1.4.1.4
  - Hyrdrophobic Membrane 1.4.2
    - Design & Analysis 1.4.2.1
    - Procure 1.4.2.2
    - Manufacture 1.4.2.3
    - Test 1.4.2.4
  - End Caps 1.4.3
    - Design & Analysis 1.4.3.1
    - Procure 1.4.3.2
    - Manufacture 1.4.3.3
  - End Plates 1.4.4
    - Design & Analysis 1.4.4.1
    - Procure 1.4.4.2
    - Manufacture 1.4.4.3
  - O-Rings 1.4.5
    - Design & Analysis 1.4.5.1
    - Procure 1.4.5.2
  - Stiffener 1.4.6
    - Design & Analysis 1.4.6.1
    - Procure 1.4.6.2
    - Manufacture 1.4.6.3
  - Glue 1.4.7
    - Design & Analysis 1.4.7.1
    - Procure 1.4.7.2
  - Hardware Assembly 1.4.8

DEVELOPING THE PLAN

- ❑ The WBS provided a document outline to begin
- ❑ A WBS dictionary from another project was used as a reference to draft a “straw man” document
- ❑ The project team developed definitions together
- ❑ This was an iterative process that resulted in some minor WBS revisions (*important point*)
- ❑ Activities required to complete WBS elements were discussed in some detail

EXAMPLE OF A WBS DICTIONARY

1. **Gas Trap Insert – Unless otherwise stated, each WBS element is to include all elements of cost (i.e. procurements, labor, & indirect costs).**

1.1. Management – Includes all aspects of program & project management, control, and coordination.

1.1.1. ISS Program Office (ISSPO) – All activities involving personnel from the ISSPO. Also includes those authorized to act on behalf of the ISSPO that are not assigned to the project by the MSFC project manager.

1.1.2. Project Management – All activities required to manage the project according to the applicable NPD, NPG, MMI, and MWI including, but not limited to: the Project Manager's time; development, administration, and maintenance of the Project Plan, Project Risk Plan, Project WBS & WBS Dictionary, and other required documentation not specifically covered elsewhere; and project meetings and reviews (formal and informal).

1.1.3. Project Control – All activities required by applicable NPD, NPG, MMI and MWI including, but not limited to: creating, updating, and maintaining the project schedule(s); and cost estimation, monitoring, measurement, analysis, and control measures, including all activities related to establishing an Earned Value System (EVS).

1.2. Systems Engineering & Integration

1.2.1. Specifications

1.2.1.1. Interfaces – All activities associated with identifying and documenting interfaces between the Gas Trap Insert and other components and systems it will interact with.

1.2.1.2. Requirements – All activities associated with identifying and documenting system-level requirements for the Gas Trap Insert.

1.2.2. Conceptual Design – All activities related to the identified trade studies, which are: Hydrophilic Membrane (New Material); Hydrophilic Membrane (Coating Material & Application); Hydrophobic Membrane (Single vs. Multiple); End Caps (New Material); and End Plates (Single vs. Multiple Hydrophobic Membranes).

1.2.3. Component & Systems Integration – All activities related to the determination of chemical and mechanical compatibility between all of the Gas Trap Insert hardware pieces, as well as the Gas Trap Insert Assembly's compatibility with the environment in which it is to be installed.

1.2.4. Configuration & Data Management

1.2.4.1. Configuration Management – All activities covering the control of Configuration Identification, Control, Accounting and Verification of the Design Requirements, Design, and Hardware documentation for the Project.

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1.2.4.2. Data Management – All activities covering the Management of Project Data from initiation of the Project to Completion and termination of the Operations of the

1.2.5. Verification – All activities related to or inspection of all hardware for the purpos with other affected hardware or systems and fulfill its intended function.

1.3. Safety & Mission Assurance

1.3.1. Safety – All activities related to ensur hardware, and the environment (earth and s

1.3.2. Reliability – All activities related to e improving the reliability and maintainabilit

1.3.3. Quality – All activities involving the improvement of product quality.

1.4. Gas Trap Hardware

1.4.1. Hydrophilic Membrane – All activitie analysis, procurement, manufacture, and tes any required coating materials.

1.4.2. Hydrophobic Membrane - All activiti analysis, procurement, manufacture, and tes

1.4.3. End Caps - All activities concerning t and manufacture of this component.

1.4.4. End Plates - All activities concerning procurement, and manufacture of this comp

1.4.5. O-Rings - All activities concerning th procurement of this component.

1.4.6. Stiffener - All activities concerning th and manufacture of this component.

1.4.7. Glue - All activities concerning the d of this component.

1.4.8. Hardware Assembly – All activities r components identified in this section (1.4). Trap Insert Housing provided (not within th

1.5. Ground Systems

1.5.1. Facilities – All activities involving th (used up in ground processes, do not remai including the modification, development, a

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1.5.2. Transportation – All activities involving the movement of the developed hardware components and Gas Trap Insert assembly to include shipping containers.

1.5.3. Ground Support Equipment (GS

1.5.3.1. Mechanical GSE (MGSE) – modification, development, pr support equipment.

1.5.3.2. Electrical GSE (EGSE) - Al development, procurement, an

1.6. Testing & Evaluation

1.6.1. Qualification – All activities re Insert meets the design requirements.

1.6.2. Acceptance – All activities requ Insert meets all applicable workmans

1.6.3. Fleet Leader – All activities req Insert meets limited life requirements.

1.6.3.1. Contamination – All activiti Trap Insert meets performanc

1.6.3.2. Gas Removal - All activities Trap Insert meets performanc

1.7. Sustaining Engineering – All activitie evaluate hardware performance, and hard pertaining to the Gas Trap Insert.

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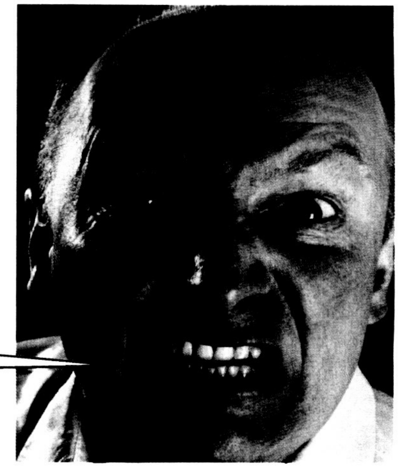
DIVERGING PATHS (REALLY?)

- Yes AND No - parts of schedule development ***can*** done in parallel with parts of estimate development, but other parts of schedule development ***must*** be done ***before*** the estimate ***can be completed***
- Schedule Development
  - The WBS outline was used to create an initial schedule structure – actually, just a list of activities with no sequence
  - The schedule development effort began by better defining the activities (i.e. adding detail where needed)
  - Once defined, the process of relating the activities to one another sequentially (i.e. establishing network logic) began
  - No date constraints were used except for the Project Start
  - Technical performance measures (TPM's) were discussed, agreed upon, and documented (***important point***) – there are many varied methods

EXAMPLES OF TPM'S (1 OF 2)

- Percent Complete
  - Subjective – requires someone to estimate physical progress
    - Least desirable, most used

"I'd say we're about 25% complete"

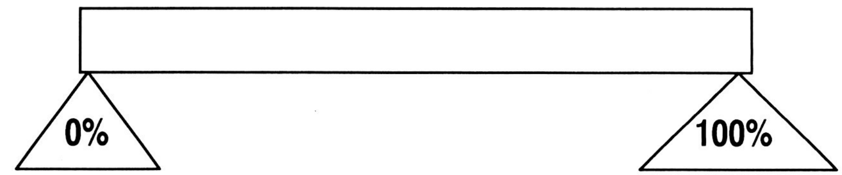


  - Objective – utilizes physical counts to determine progress
    - Most desirable, least used

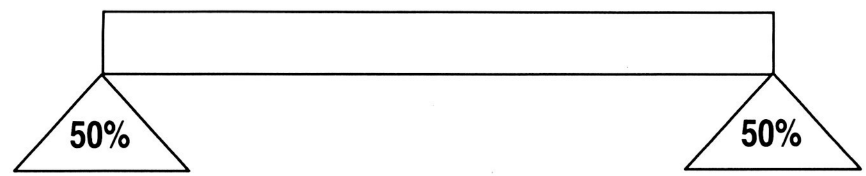
"We've built 50 of the 100 widgets, therefore we're 50% complete"

EXAMPLES OF TPM'S (2 OF 2)

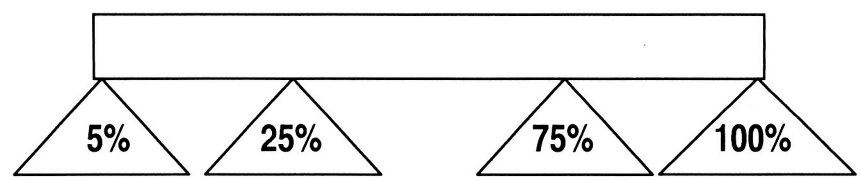
- Milestone
  - 0-100%- credit is only earned upon completion (100%)
    - Typically used when tasks span <= 1 acct. period



  - 50-50%- credit is given at the start (50%) and finish (50%)
    - Typical for tasks spanning 2-3 acct. periods



  - Weighted – partial credit is given at key interims
    - Used when tasks span more than 3 acct. periods



NOTE ON MILESTONE TPM: REQUIRES THE USE OF A TRACKING PROCESS

DIVERGING PATHS (REALLY?)

- Schedule Development (Continued)
  - The tasks of making duration estimates and doing resource identification, assignments and allocations were done hand-in-hand since the skill level (for people) and availability of resources have a direct impact on the activity duration
  - Not one, but three duration estimates were collected for each schedule activity (best case, worst case, most likely – more on this later)
  - Every work group (engineers, manufacturing, etc.) participated in developing the schedule – this resulted in a highly integrated plan
  - This process was iterative – adjustments to the sequencing of activities and allocation of resources were made until all stakeholders were satisfied with the results
  - As duration estimates were finalized, the SAME PEOPLE provided inputs for the cost estimates

EXAMPLE SCHEDULE BASED ON WBS

ID	WBS	
71	1.4.4.1	
72	1.4.4.2	
73	**1.4.4.3**	
74	1.4.4.3.1	
75	1.4.4.3.2	
76	**1.4.5**	
77	1.4.5.1	
78	1.4.5.2	
79	**1.4.6**	
80	1.4.6.1	
81	1.4.6.2	
82	**1.4.6.3**	
83	1.4.6.3.1	
84	1.4.6.3.2	
85	**1.4.7**	
86	1.4.7.1	
87	1.4.7.2	
88	**1.4.8**	
89	1.4.8.1	
90	1.4.8.2	
91	**1.5**	G
92	1.5.1	
93	1.5.2	
94	**1.5.3**	
95	1.5.3.1	
96	1.5.3.2	
97	**1.6**	T
98	1.6.1	
99	1.6.2	
100	**1.6.3**	
101	1.6.3.1	
102	1.6.3.2	
103	**1.7**	S

Project: Gas Trap Insert
Date: Mon 8/30/04

ID	WBS	
36	1.2.2.5	
37	**1.2.3**	
38	**1.2.4**	
39	1.2.4.1	
40	1.2.4.2	
41	**1.3**	Sa
42	1.3.1	
43	1.3.2	
44	1.3.3	
45	**1.4**	Gi
46	**1.4.1**	
47	1.4.1.1	
48	1.4.1.2	
49	**1.4.1.3**	
50	1.4.1.3.1	
51	1.4.1.3.2	
52	**1.4.1.4**	
53	1.4.1.4.1	
54	1.4.1.4.2	
55	**1.4.2**	
56	1.4.2.1	
57	1.4.2.2	
58	**1.4.2.3**	
59	1.4.2.3.1	
60	1.4.2.3.2	
61	**1.4.2.4**	
62	1.4.2.4.1	
63	1.4.2.4.2	
64	**1.4.3**	
65	1.4.3.1	
66	1.4.3.2	
67	**1.4.3.3**	
68	1.4.3.3.1	
69	1.4.3.3.2	
70	**1.4.4**	

Project: Gas Trap Insert
Date: Mon 8/30/04

ID	WBS	Task Name	2004–2007 (Qtr 3 2003 – Qtr 4 2007)
1	**1**	**Gas Trap Insert**	
2	**1.1**	**Management**	
3	1.1.1	ISSPO Support - LOE	IND
4	**1.1.2**	**Project Management**	
5	1.1.2.1	Project Management - LOE	CS,MAT,TRV
6	*1.1.2.2*	*Authorization To Proceed*	1/1
7	*1.1.2.3*	*Project Plan Development*	
8	*1.1.2.4*	*SRR Complete*	3/24
9	*1.1.2.5*	*Quality Plan Development*	
10	*1.1.2.6*	*Quality Plan Approved*	4/21
11	*1.1.2.7*	*PDR Complete*	8/11
12	*1.1.2.8*	*CDR Complete*	11/1
13	*1.1.2.9*	*Hardware Design Complete*	11/26
14	*1.1.2.10*	*All Drawings Reviewed & Released*	12/24
15	*1.1.2.11*	*Procurement Complete*	4/13
16	*1.1.2.12*	*Qualification Testing Complete*	8/31
17	*1.1.2.13*	*Qualification Review*	
18	*1.1.2.14*	*Fleet Leader Testing Begins*	9/7
19	*1.1.2.15*	*Manufacturing Complete*	11/22
20	*1.1.2.16*	*All Membrane Testing Complete*	12/20
21	*1.1.2.17*	*Acceptance Testing Complete*	7/4
22	*1.1.2.18*	*Program Acceptance & Final Pre-ship Review*	
23	*1.1.2.19*	*All Units Shipped*	7/18
24	*1.1.2.20*	*Schedule Margin*	Schedule Margin
25	*1.1.2.21*	*Project Complete*	1/2
26	1.1.3	Project Controls - LOE	CS
27	**1.2**	**Systems Engineering**	
28	**1.2.1**	**Specification Development**	
29	1.2.1.1	Interface Development	CS,FTS
30	1.2.1.2	Requirements Development	CS,FTS
31	**1.2.2**	**Conceptual Design**	
32	1.2.2.1	Trade Study - Hydrophilic Membrane (Material Type)	CS
33	1.2.2.2	Trade Study - Membrane Coating (Material & Application)	CS
34	1.2.2.3	Trade Study - Hydrophobic Membrane (Single vs. Multiple)	CS
35	1.2.2.4	Trade Study - End Caps (Material Type)	CS

Project: Gas Trap Insert
Date: Mon 8/30/04

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Revision: D

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DIVERGING PATHS (REALLY?)

- Estimate Development
  - Initial estimates were compiled by combining work group leads' estimates (i.e. X heads for Y months) with rates for labor, procurements, and indirect costs – this process was heavily influenced by historical data
  - As schedule development evolved, costs for resources were loaded in the schedule tool and the resulting time-phased cost plan from the schedule tool was compared with initial estimates
  - The cost, schedule, and work groups collaborated to reconcile the gaps between cost and schedule
  - Initial reserves (cost and schedule) were added based on historical data, but later reviewed and revised (see Establishing the Baseline)

EXAMPLE ESTIMATE WORKSHEET

Object Level			FY05	FY06	FY07	TOTAL
9051	Civil Service	FTE's				
9052	Contractor on-site	WYE's				
	Workforce total					
1000	Personnel	Direct Civil Service FTE x rate (Salary & Fringe)				
2100	Travel					
3000	Procurement	Contracts, grants, hardware, direct services				
	SUB TOTAL Direct Cost					
8020	Service Pools	(FTE+WYE)*Service Pool rate				
8005	Center G&A	(FTE+WYE)*Center G&A rate				
8000	Corp G&A	(FTE+WYE)*Corp. G&A rate				
		Total Full Cost Budget Plan				
		Reserve (15% - held by ISSPO/OB)				
		Grand Total				

CONVERGING PATHS

- Risky Business
  - The schedule data was used to initially populate a Risk Log template (including best case, worst case, and most likely duration estimates for use later)
  - The project team adopted a list of risk-types that applied to the project (e.g. design engineering difficulty, manufacturing process difficulty, etc.)
  - For each risk-type, the project team defined a scale that consisted of numbers with a description for each number (e.g. a “0” for design engineering difficulty might mean “we do it all the time” while a “25” might mean “never done before”)
  - The same type of scale was developed for the consequence of risk materialization as well
  - The Risk Log items were examined by the project team and risks were rated using the scales developed as described in the preceding steps
  - These risk ratings were converted via formulas into a Performance Difficulty factor, as well as an overall Risk Factor, for each Risk Log item
  - The results were plotted on a standard 5 X 5 Risk Matrix and ranked

EXAMPLE RISK TEMPLATE (1 of 3)

LEGEND

SOT	State of Technology	See Table 1
DED	Design Engineering Difficulty	See Table 2
MPD	Manufacturing Process Difficulty	See Table 3
EQI	Production Equipment Resources	See Table 4
MAT	Material Resources	See Table 5
PER	Personnel Resources	See Table 6
TST	Test Resources	See Table 7
Cf	Consequence of Failure	See Table 8
Pt	Performance difficulty due to Technological risks	(SOT X DED) / 625
Pm	Performance difficulty due to Manufacturing risks	MPD X (EQI + MAT + PER + TST) / 2500
Pd	Performance Difficulty	Pd = Pt + Pm - (Pt X Pm)
RF	Risk Factor	Pd X Cf

MANUFACTURING PROCESS DIFFICULTY (MPD)	RATING
NO COMPARABLE PROCESS, AND AT LEAST ONE OF: C, Y, T, TP, OR PC IS EXPECTED TO EXCEED STATE OF ART	25
NO COMPARABLE PROCESS, AND ALL OF THE REQUIREMENTS FOR C, Y, T, TP, OR PC ARE EXPECTED TO BE WITHIN THE STATE OF THE ART	16
INTEGRATED PROCESS IS A COMBINATION OF DEMONSTRATED PROCESSES AND C, Y, T, TP, OR PC EXCEED NORM FOR THESE PROCESSES	12
INTEGRATED PROCESS IS A COMBINATION OF EXISTING PROCESSES AND C, Y, T, OR TP ARE WITHIN THE NORM FOR THESE PROCESSES	6
MODIFICATIONS OF EXISTING INTEGRATED PROCESS TO ACHIEVE C, Y, T, TP, OR PC	3
EXISTING PROCESS; MEETS C, Y, T, TP, AND REQUIREMENTS WHERE: Y =YIELD; T =TOLERANCE AND/OR PRECISION; TP =THROUGH PUT; C =COMPLEXITY; PC =PROCESS CONTROLS	0

Table 3

PRODUCTION EQUIPMENT STATUS (EQI)	RATING
INSUFFICIENT FACILITIES AND EQUIPMENT, DEVELOPMENT REQUIRED	25
FACILITY AVAILABLE, AND EQUIPMENT DEVELOPMENT REQUIRED	18
FACILITY/EQUIPMENT AVAILABLE BUT REQUIRE MINOR EQUIPMENT MODIFICATIONS TO CONFORM TO PROCESS	12
FACILITY AVAILABLE, EQUIPMENT DEVELOPMENT COMPLETE, INSUFFICIENT QUANTITY OF EQUIPMENT	9
FACILITY/EQUIPMENT AVAILABLE – REFURBISHMENT REQUIRED	6
FACILITY/EQUIPMENT AVAILABLE, LIMITED USE IN DESIGNATED PRODUCTION	3
FACILITY/EQUIPMENT BEING USED TO MANUFACTURE GIVEN PRODUCT	0

Table 4

PERSONNEL RESOURCE STATUS (PER)	RATING
RESEARCH PERSONNEL REQUIRED FOR PRODUCTION	25
INSUFFICIENT HIGH SKILLED PRODUCTION PERSONNEL	20
INSUFFICIENT MODERATE/LOW SKILLED PRODUCTION PERSONNEL	15
SUFFICIENT PRODUCTION PERSONNEL BUT TRAINING REQUIRED	10
SUFFICIENT TRAINED PRODUCTION PERSONNEL	5
SUFFICIENT TRAINED PRODUCTION PERSONNEL INVOLVED IN ON GOING PRODUCTION	0

Table 6

TEST RESOURCE STATUS (TEST)	RATING
NO DEFINED TEST PROCEDURES, NO EQUIPMENT AND NO FACILITIES	25
DEFINED PROCEDURES, INSUFFICIENT EQUIPMENT/FACILITY: CUSTOM EQUIPMENT DESIGN REQUIRED	20
DEFINED PROCEDURES, FACILITY AVAILABLE, CUSTOM EQUIPMENT DESIGN REQUIRED	18
DEFINED PROCEDURES, FACILITY AVAILABLE, STANDARD EQUIPMENT REQUIRED BUT INSUFFICIENT EQUIPMENT AVAILABLE	12
DEFINED PROCEDURES, FACILITY AVAILABLE REQUIRED EQUIPMENT AVAILABLE BUT MINOR MODIFICATIONS REQUIRED	8
DEFINED PROCEDURES, FACILITY AVAILABLE, EQUIPMENT AVAILABLE BUT REFURBISHMENT REQUIRED	5
DEFINED PROCEDURES, FACILITY AVAILABLE, EQUIPMENT	3

STATE OF TECHNOLOGY (SOT)	RATING
SCIENTIFIC RESEARCH ON-GOING	25
CONCEPT DESIGN FORMULATED FOR PERFORMANCE AND QUALIFICATIONS	20
CONCEPT DESIGN TESTED FOR PERFORMANCE AND QUALIFICATION CONCERNS	10
CRITICAL FUNCTION/CHARACTER DEMONSTRATED AT BREADBOARD FABRICATED AND TESTED FOR PERFORMANCE	7
BRASSBOARD FABRICATED AND TESTED FOR PERFORMANCE AND QUALIFICATIONS	5
PROTOTYPE HARDWARE IN TEST. PASSED PERFORMANCE REQUIREMENTS	3
PROTOTYPE HARDWARE PASSED QUALIFICATION TESTS	2
MANUFACTURING PROCESS DEFINED	1
CURRENTLY OPERATIONAL AND DEPLOYED	0

Table 1

DESIGN ENGINEERING DIFFICULTY (DED)	RATING
NO ALTERNATIVE AND/OR REQUIRES NEW OR BREAKTHROUGH ADVANCE	25
NO ALTERNATIVE AND/OR MAJOR ENGINEERING DEVELOPMENT USING EXISTING KNOWLEDGE	20
POOR ALTERNATIVES AND/OR NEW COMPONENT DEVELOPMENT IS REQUIRED	15
POOR ALTERNATIVES AND/OR USES STANDARD COMPONENTS BEYOND ACCEPTED SPEC LEVEL	12
DESIGN EFFORT REQUIRED USING STANDARD COMPONENTS WITHIN SPECS	9
OFF-THE-SHELF ITEM WITH MINOR MODIFICATIONS	6
OFF-THE-SHELF ITEM WHICH REQUIRES QUALIFICATION	3
QUALIFIED OFF-THE-SHELF ITEM WHICH MEETS ALL REQUIREMENTS	0

Table 2

MATERIAL RESOURCE STATUS (MAT)	RATING
NO DEFINED SOURCE	25
SINGLE OFFSHORE SOURCE IDENTIFIED WITH INSUFFICIENT MATERIAL PRODUCTION	23
SINGLE U.S. SOURCE IDENTIFIED WITH INSUFFICIENT MATERIAL PRODUCTION	20
MULTIPLE OFF-SHORE SOURCE IDENTIFIED WITH INSUFFICIENT MATERIAL PRODUCTION	18
SINGLE OFF-SHORE SOURCE IDENTIFIED WITH SUFFICIENT MATERIAL PRODUCTION	16
MULTIPLE OFF-SHORE SOURCE IDENTIFIED WITH SUFFICIENT MATERIAL	15
SINGLE U.S. SOURCE IDENTIFIED WITH SUFFICIENT MATERIAL	10
MULTIPLE U.S. SOURCES WITH SUFFICIENT MATERIAL	0

Table 5

Consequence of Failure (Cf) Scale

Rating	Consequences
0.1	NEGLIGIBLE -- Failure to meet the requirement would create inconvenience or non-operational impact. No significant performance.
0.3	MINOR -- Failure to meet requirement results in minor reduction in mission achievement. Small performance reduction.
0.5	MARGINAL -- Failure to meet requirement results in degradation of secondary mission. Significant reduction in technical performance
0.7	CRITICAL -- Failure to meet requirement results would degrade performance to a point that primary mission success in danger.
0.9	CATASTROPHIC -- Failure to meet the requirement results in mission failure, vehicle destruction, loss of life

Table 8

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Probability Distribution Curve

0. Fixed
1. Uniform
2. Triangular
3. Normal

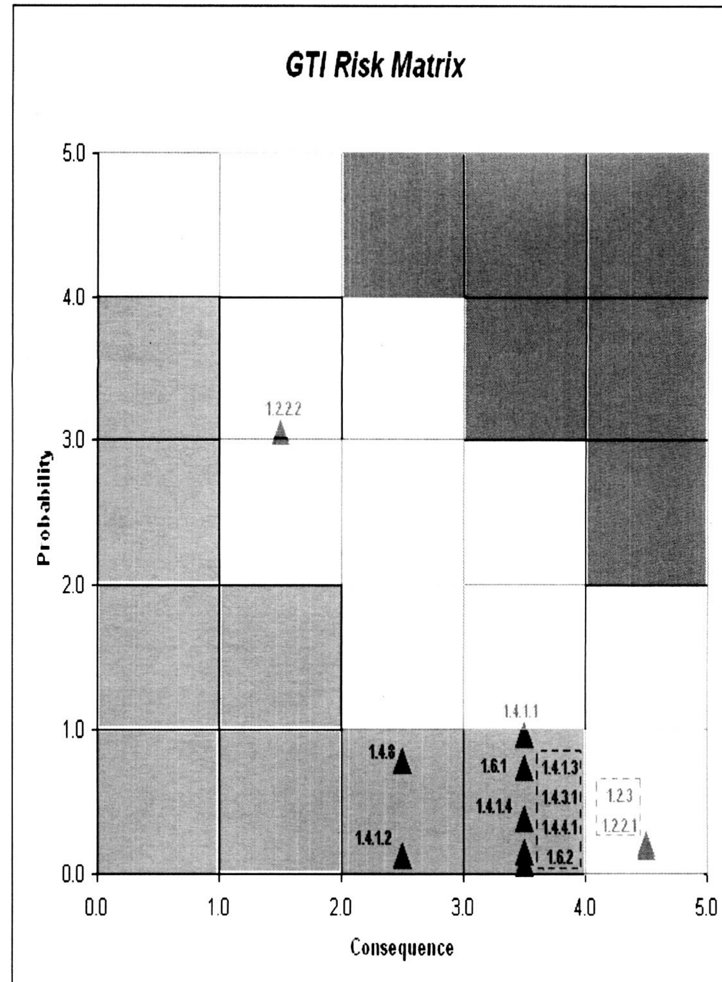
JACOBS SVERDRUP

EXAMPLE RISK TEMPLATE (2 of 3)

WBS	Title	Risk ID	Risk Description	SOT	DED	MPD	EQI	MAT	PER	TST	Cf	Pt	Pm	Pd	RF
1.0	*Gas Trap Insert*														0.72
1.1	**Management**														0.00
1.1.1	ISSPO											0.000	0.000	0.000	0.00
1.1.2	Project Management											0.000	0.000	0.000	0.00
1.1.3	Project Control		Acquiring a knowledgeable professional.	0	0	0	0	0	5	0	0.5	0.000	0.000	0.000	0.00
1.2	**Systems Engineering & Integration**														0.25
1.2.1	Specifications														0.00
1.2.1.1	Interfaces											0.000	0.000	0.000	0.00
1.2.1.2	Requirements											0.000	0.000	0.000	0.00
1.2.2	Conceptual Design														0.22
1.2.2.1	Trade Study - Hydrophilic Membrane (Material Type)		New material desired (operational enhancements).	1	2	6	1	5	5	3	0.9	0.003	0.034	0.037	0.03
1.2.2.2	Trade Study - Membrane Coating (Material & Application)		New coating material & application technique.	10	15	20	18	5	20	18	0.3	0.240	0.488	0.611	0.18
1.2.2.3	Trade Study - Hydrophobic Membrane (Single vs. Multiple)		Desired performance enhancement doesn't work.	1	1	3	1	0	1	1	0.1	0.002	0.004	0.005	0.00
1.2.2.4	Trade Study - End Caps (Material Type)		Change to reduce swelling doesn't work.	1	1	0	3	5	5	2	0.1	0.002	0.000	0.002	0.00
1.2.2.5	Trade Study - End Plates (Hydrophilic Membrane Trade)		Satisfactory attachment of multiple membranes.	1	1	0	3	5	5	2	0.1	0.002	0.000	0.002	0.00
1.2.3	Component & Systems Integration		Mechanical or chemical compatibility issues.	1	3	3	3	5	15	8	0.9	0.005	0.037	0.042	0.04
1.2.4	Configuration & Data Management														0.00
1.2.4.1	Configuration Management			25	0	0	0	0	0	0	0	0.000	0.000	0.000	0.00
1.2.4.2	Data Management											0.000	0.000	0.000	0.00
1.3	**Safety & Mission Assurance**														0.00
1.3.1	Safety											0.000	0.000	0.000	0.00
1.3.2	Reliability											0.000	0.000	0.000	0.00
1.3.3	Quality											0.000	0.000	0.000	0.00
1.4	**Gas Trap Hardware**														0.34
1.4.1	Hydrophilic Membrane														0.22
1.4.1.1	Hydrophilic Membrane Design & Analysis		Detailed design reveals fatal flaw - start over.	10	12	0	0	0	5	0	0.7	0.192	0.000	0.192	0.13
1.4.1.2	Hydrophilic Membrane Procurement		Material not available in the time frame required.	0	0	6	0	5	5	0	0.5	0.000	0.024	0.024	0.01
1.4.1.3	Hydrophilic Membrane Manufacturing		Facilities not available in the time frame needed.	0	0	6	6	5	1	0	0.7	0.000	0.029	0.029	0.02
1.4.1.4	Hydrophilic Membrane Testing		Testing reveals flaw - start over	7	6	3	0	0	5	3	0.7	0.067	0.010	0.076	0.05
1.4.2	Hydrophobic Membrane														0.01
1.4.2.1	Hydrophobic Membrane Design & Analysis		Detailed design reveals fatal flaw - start over.	1	1	0	0	0	1	0	0.7	0.002	0.000	0.002	0.00
1.4.2.2	Hydrophobic Membrane Procurement		Material not available in the time frame required.	0	0	1	0	5	5	0	0.5	0.000	0.004	0.004	0.00
1.4.2.3	Hydrophobic Membrane Manufacturing		Facilities not available in the time frame needed.	0	0	1	1	1	1	0	0.7	0.000	0.001	0.001	0.00
1.4.2.4	Hydrophobic Membrane Testing		Testing reveals flaw - start over	1	1	1	0	0	1	1	0.7	0.002	0.001	0.002	0.00
1.4.3	End Caps														0.01
1.4.3.1	End Caps Design & Analysis		Detailed design reveals fatal flaw - start over.	3	3	0	0	0	5	0	0.7	0.014	0.000	0.014	0.01
1.4.3.2	End Caps Procurement		Material not available in the time frame required.	0	0	1	1	5	0	0	0.5	0.000	0.002	0.002	0.00
1.4.3.3	End Caps Manufacturing		Facilities not available in the time frame needed.	0	0	1	1	5	5	0	0.7	0.000	0.004	0.004	0.00
1.4.4	End Plates														0.01
1.4.4.1	End Plates Design & Analysis		Detailed design reveals fatal flaw - start over.	3	3	0	0	0	5	0	0.7	0.014	0.000	0.014	0.01
1.4.4.2	End Plates Procurement		Material not available in the time frame required.	0	0	1	1	5	0	0	0.5	0.000	0.002	0.002	0.00
1.4.4.3	End Plates Manufacturing		Facilities not available in the time frame needed.	0	0	1	1	5	5	0	0.7	0.000	0.004	0.004	0.00
1.4.5	O-Rings														0.00
1.4.5.1	O-Rings Design & Analysis		Detailed design reveals fatal flaw - start over.	1	1	0	0	0	0	0	0.7	0.002	0.000	0.002	0.00
1.4.5.2	O-Rings Procurement		Material not available in the time frame required.	0	0	1	0	1	1	0	0.5	0.000	0.001	0.001	0.00
1.4.6	Stiffener														0.01
1.4.6.1	Stiffener Design & Analysis		Detailed design reveals fatal flaw - start over.	1	3	0	0	0	1	0	0.7	0.005	0.000	0.005	0.00
1.4.6.2	Stiffener Procurement		Material not available in the time frame required.	0	0	3	0	1	0	0	0.5	0.000	0.001	0.001	0.00
1.4.6.3	Stiffener Manufacturing		Facilities not available in the time frame needed.	0	0	3	1	1	1	0	0.5	0.000	0.004	0.004	0.00
1.4.7	Glue														0.08
1.4.7.1	Glue Design & Analysis		Detailed design reveals fatal flaw - start over.	1	1	0	0	0	0	0	0.7	0.002	0.000	0.002	0.00
1.4.7.2	Glue Procurement		Material not available in the time frame required.	0	0	1	0	1	1	0	0.5	0.000	0.001	0.001	0.00
1.4.8	Hardware Assembly		Parts lost or damaged - rework	5	9	12	7	1	10	1	0.5	0.072	0.091	0.157	0.08
1.5	**Ground Systems Development**														0.00
1.5.1	Facilities Development											0.000	0.000	0.000	0.00
1.5.2	Transportation Development											0.000	0.000	0.000	0.00
1.5.3	GSE Development														0.00
1.5.3.1	MGSE Development											0.000	0.000	0.000	0.00
1.5.3.2	EGSE Development											0.000	0.000	0.000	0.00
1.6	**Testing & Evaluation**														0.12
1.6.1	Qualification Testing		Test fails - rework	5	3	12	6	5	5	10	0.7	0.024	0.125	0.146	0.10
1.6.2	Acceptance Testing		Test fails - rework	2	0	3	3	5	1	3	0.7	0.000	0.014	0.014	0.01
1.6.3	Fleet Leader Testing														0.01
1.6.3.1	Contamination Testing		Test fails - rework	2	0	3	3	5	1	5	0.3	0.000	0.017	0.017	0.01
1.6.3.2	Gas Removal Testing		Test fails - rework	2	0	3	3	5	1	5	0.3	0.000	0.017	0.017	0.01
1.7	**Sustaining Engineering**											0.000	0.000	0.000	0.00

EXAMPLE RISK TEMPLATE (3 of 3)

WBS	Title	Cf	Pd	RF
1.2.2.1	Trade Study - Hydrophilic Membrane (Material Type)	1.5	3.1	0.18
1.2.2.2	Trade Study - Membrane Coating (Material & Application)	3.5	1.0	0.13
1.2.3	Component & Systems Integration	3.5	0.7	0.10
1.4.1.1	Hydrophilic Membrane Design & Analysis	2.5	0.8	0.08
1.4.1.2	Hydrophilic Membrane Procurement	3.5	0.4	0.05
1.4.1.3	Hydrophilic Membrane Manufacturing	4.5	0.2	0.04
1.4.1.4	Hydrophilic Membrane Testing	4.5	0.2	0.03
1.4.3.1	End Caps Design & Analysis	3.5	0.1	0.02
1.4.4.1	End Plates Design & Analysis	2.5	0.1	0.01
1.4.8	Hardware Assembly	3.5	0.1	0.01
1.6.1	Qualification Testing	3.5	0.1	0.01
1.6.2	Acceptance Testing	3.5	0.1	0.01



ESTABLISHING THE BASELINE

- The risk data, along with data collected during interviews, was used to characterize schedule tasks
- This characterization and the 3 duration estimates collected earlier were used to perform a schedule risk assessment
- Since the schedule was resource loaded and resources were costed, a cost risk assessment was performed simultaneously
- The results of both assessments were used to determine the needed cost and schedule reserves
- These reserve numbers were compared to the initial reserve estimates and an informed decision was made – THE BASELINE WAS ESTABLISHED

RESERVE JUSTIFICATION

Cost Reserve Justification

Assumptions

- Desired reserve is 10-20% (based on historical data).
- Cost and risk estimates are accurate and complete as of the time of this analysis.
- All planned work has an estimated cost and is identified in the schedule.
- Total project costs are estimated to be $X,XXXK.

Basis

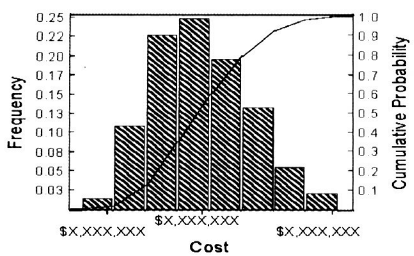
- Cost is directly proportional to the cost of resources and the duration of the task.
- Certain indirect, travel, material, facility/test support, and level-of-effort costs are fixed.
- There are widely varying levels of risk associated with different tasks.

Analysis

- The project was evaluated as a whole and each section was analyzed independently.
- A combined approach is recommended to ascertain the most accurate results.
- At a project level, an 80% level of confidence can be obtained for $X,XXXK.
- This represents a reserve of $XXXK for estimate uncertainty.

Date: 11/10/2003 2:47:22 PM
Samples: 1000
Unique ID: 1
Name: Gas Trap Insert

Cost Standard Deviation: $XX,XXX
95% Confidence Interval: $X,XXX
Each bar represents $XX,000.00



11th run - revised CS FTE and other costs

Cost Probability Table

Prob	Cost	Prob	Cost
0.05	$X,XXX,XXX	0.55	$X,XXX,XXX
0.10	$X,XXX,XXX	0.60	$X,XXX,XXX
0.15	$X,XXX,XXX	0.65	$X,XXX,XXX
0.20	$X,XXX,XXX	0.70	$X,XXX,XXX
0.25	$X,XXX,XXX	0.75	$X,XXX,XXX
0.30	$X,XXX,XXX	0.80	$X,XXX,XXX
0.35	$X,XXX,XXX	0.85	$X,XXX,XXX
0.40	$X,XXX,XXX	0.90	$X,XXX,XXX
0.45	$X,XXX,XXX	0.95	$X,XXX,XXX
0.50	$X,XXX,XXX	1.00	$X,XXX,XXX

- Using mean data, the table below represents recommended additions to the reserve.

Element	Description	Estimated Cost ($K)	Mean Cost ($K)	Recommended Reserve Add ($K)
1.4	Hardware	$ X,XXX	$ X,XXX	$ XX
1.6	Testing & Evaluation	$ XXX	$ XXX	$ XX
				$ XX

- The basis for fixed costs is not valid, therefore it is recommended that an additional 5% be alloted to cover these costs (based on the schedule reserve analysis).

Reserve Build Up

	$K	Project Estimate	Total Project Cost
Estimate Uncertainty	$ XXX		
High Risk Items	$ XX		
Fixed Costs variation	$ XXX		
TOTAL RESERVE	$ XXX	$ X,XXX	$ X,XXX

Schedule Reserve Justification

Assumptions

- Desired reserve is approximately 20% (based on historical data).
- Schedule and risk data is accurate and complete as of the time of this analysis.
- All planned work is identified in the schedule.

Basis

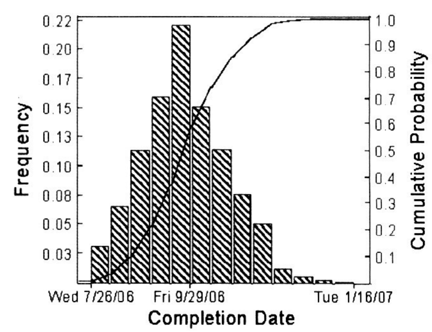
- Task duration is 2 years and 7 months.
- Project start is assumed to be 1/1/04 for the purpose of this exercise.
- Scheduled project completion date with 120 days of reserve is 1/2/07.
- The last unit is scheduled to ship on 7/18/06. This is the completion date without reserve.

Analysis

- To an 80% level of confidence, the project will be complete by 10/24/06.
- The difference between 7/18/06 and 10/24/06 is 72 working days of reserve, or about 9.3%.
- Recommend adding an additional 9.3% for unknown or unrealized risks.
- A total schedule reserve of between 120 to 150 days, or about 18-20% should be adequate.

Date: 11/10/2003 2:47:23 PM
Samples: 1000
Unique ID: 48
Name: All Units Shipped

Completion Std Deviation: 20.66 days
95% Confidence Interval: 1.28 days
Each bar represents 10 days



11th run - revised CS FTE and other costs

Completion Probability Table

Prob	Date	Prob	Date
0.05	Mon 8/14/06	0.55	Mon 10/2/06
0.10	Thu 8/24/06	0.60	Wed 10/4/06
0.15	Wed 8/30/06	0.65	Tue 10/10/06
0.20	Tue 9/5/06	0.70	Thu 10/12/06
0.25	Mon 9/11/06	0.75	Wed 10/18/06
0.30	Thu 9/14/06	0.80	Tue 10/24/06
0.35	Mon 9/18/06	0.85	Tue 10/31/06
0.40	Thu 9/21/06	0.90	Wed 11/8/06
0.45	Tue 9/26/06	0.95	Fri 11/17/06
0.50	Thu 9/28/06	1.00	Tue 1/16/07

JACOBS SVERDRUP

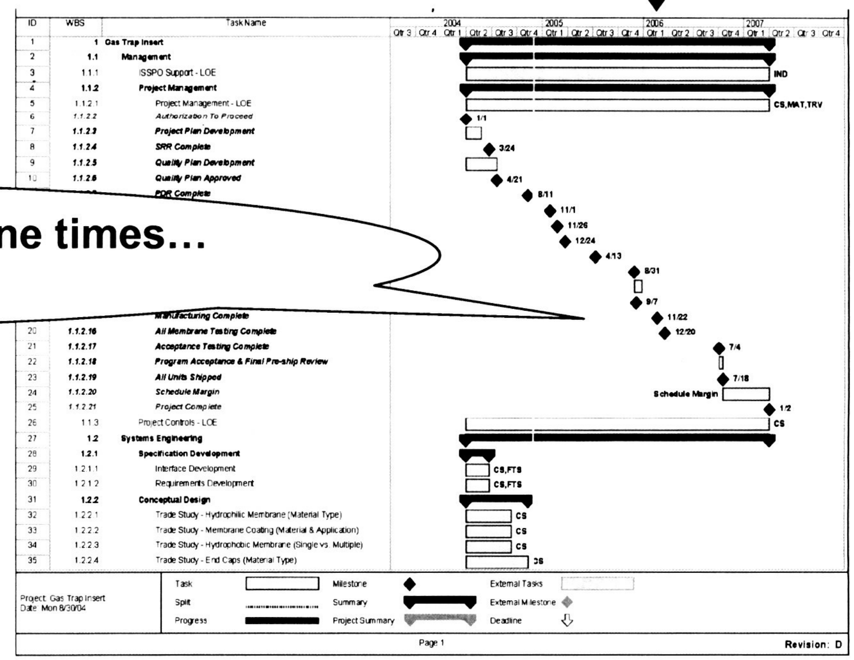
NASA

IT ALL COMES TOGETHER

- The result – a time-phased and costed plan with built-in performance measurement capability
  - Time = Schedule – Our schedule tool provided a complete list of all activities required to complete our scope of work, arranged in a logical, sequential fashion, along with the capability to assess the impact on our completion date due to changes (scope, sequence, risk materialization)
  - Dollars = Estimates – By assigning costed resources to schedule activities, we had a cost plan that not only indicated total costs, but when those costs would be incurred, along with the impact of changes (scope, sequence, risk materialization)
  - Performance = Work Accomplished – The baseline contained the record of our commitment to perform work for a specified cost during a specified time period, which could then be used to compare with actual costs and actual time as the project moved forward (this also provided us with a tool to enable forecasts of time and cost for future work planned)

IT ALL COMES TOGETHER

- Key Questions Answered
  - "How long will it take?"



Along with key project milestone times…

IT ALL COMES TOGETHER

- Key Questions Answered
  - "How much will it cost?"
  - Answer - $X M

1. Risk Assessment

2. Build Up (Estimate + Risk)

Cost Reserve Justification

Assumptions

- Desired reserve is 10-20% (based on historical data).
- Cost and risk estimates are accurate and complete as of the time of this analysis.
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- Cost is directly proportional to the cost of resources and the duration of the task.
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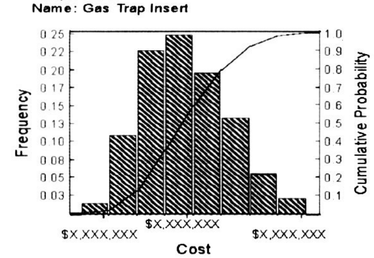

11th run - revised CS FTE and other costs

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0.15	$X,XXX,XXX	0.65	$X,XXX,XXX
0.20	$X,XXX,XXX	0.70	$X,XXX,XXX
0.25	$X,XXX,XXX	0.75	$X,XXX,XXX
0.30	$X,XXX,XXX	0.80	$X,XXX,XXX
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- Using mean data, the table below represents recommended additions to the reserv

Element	Description	Estimated Cost ($K)	Mean Cost ($K)	Recomm Reserve A
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1.6	Testing & Evaluation	$ XXX	$ XXX	$ XX
				$ XX

- The basis for fixed costs is not valid, therefore it is recommended that an add 5% be alloted to cover these costs (based on the schedule reserve analysis).

Reserve Build Up

	$K
Estimate Uncertainty	$ XXX
High Risk Items	$ XX
Fixed Costs variation	$ XXX
TOTAL RESERVE	$ XXX

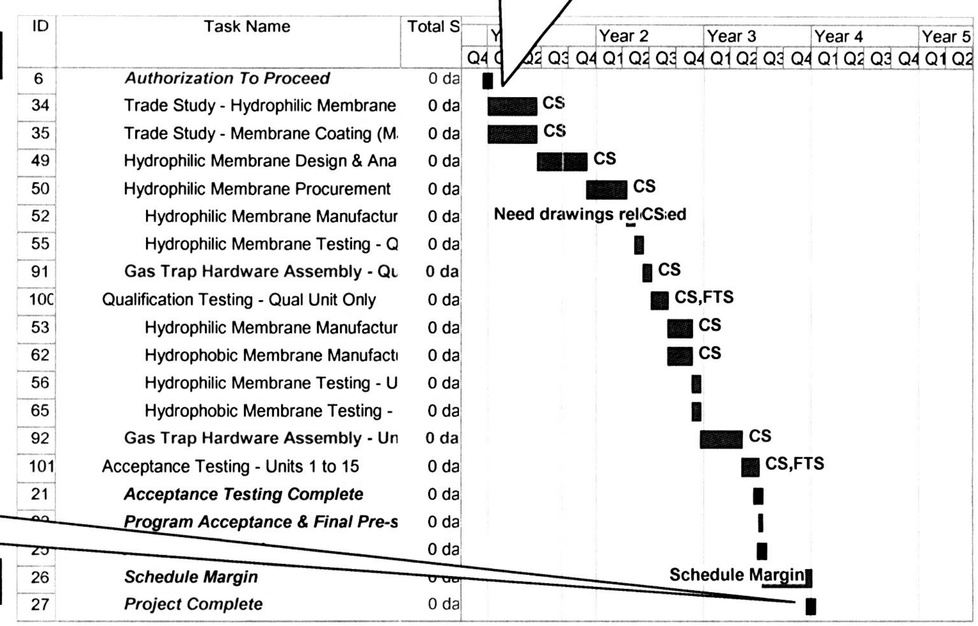
$ Project Estimat X

Total Project Cost
$ X,XXX

IT ALL COMES TOGETHER

- Key Questions Answered
  - "What's the critical path?"
  - Answer – See graphic

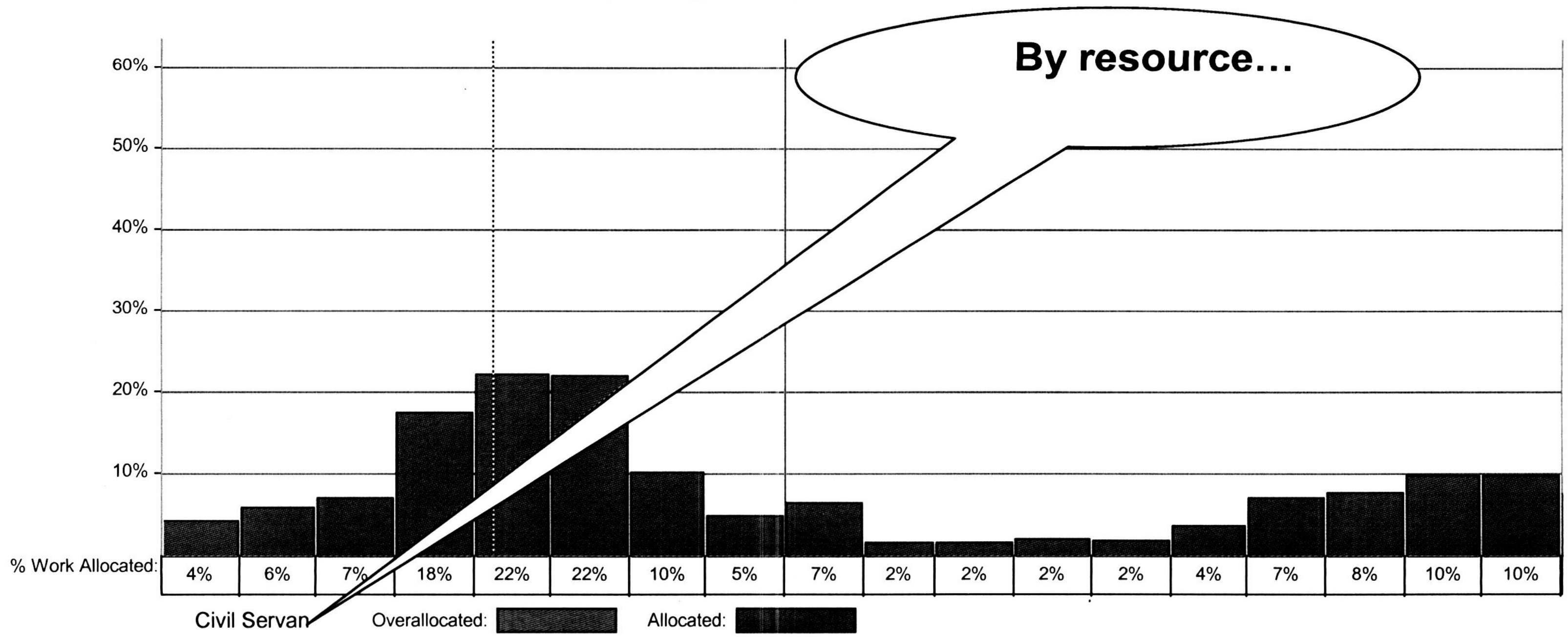
Starts at Time Now...



...and goes thru Project Completion

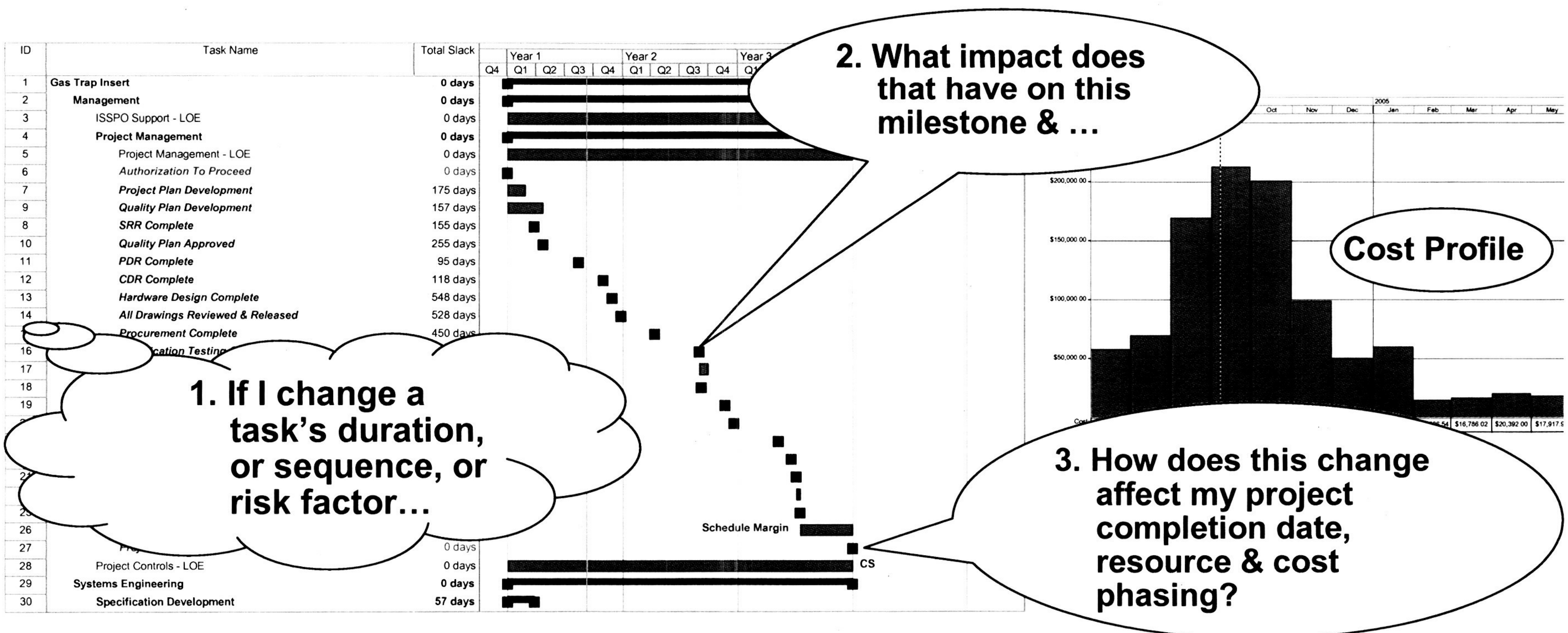
IT ALL COMES TOGETHER

- Key Questions Answered
  - "What resources are required and when?"
  - Answer – See graphic



IT ALL COMES TOGETHER

- ❑ **Key Questions Answered**
  - ❑ **"What if ….?"**
  - ❑ **Answer – Using a copy of the schedule, change sequencing or durations or risk factors and analyze the outcome…**



IT ALL COMES TOGETHER

- Changes in work scope create a "data cascade"
  - The WBS is updated
  - The WBS Dictionary is updated
  - The Schedule is updated
  - Estimates are updated
  - The Risk Log is updated
  - A new cost/schedule risk assessment is performed
  - Reserves (cost &/or schedule) adjusted accordingly
- A change in any of the following creates a similar ripple effect
  - Schedule – actual versus planned durations, revised plans
  - Cost – rate differences, resource expenditures
  - Technical – design issues, technology development issues
  - Risk – retirement of risks, new risks, evolving risks

IT ALL COMES TOGETHER

- **One key to successfully managing the project – A DISCIPLINED SYSTEM OF PROCESSES**
  - Management Philosophy – "plan the work, work the plan" approach
  - Configuration Control (WBS, WBS Dictionary, etc.)
  - Data Management (cost, schedule, etc.)
- **Another key - COMMUNICATION !!! Is there an ECHOO in here?**
  - An "ECHOO" implies repetition – necessary part of effectiveness
  - Early – gives stakeholders the most precious commodity (TIME)
  - Clearly – ensures understanding and commonality of purpose
  - Honestly – fosters teamwork and trust
  - Often – makes certain the message is received & understood
  - Openly – eliminates fear and builds the information power base
- ***Historical Note – this "package" was "bought" by our customers with only minor comments***

LESSONS LEARNED (1 of 3)

- "Lock in" the WBS before proceeding with schedule, cost, or risk efforts – this will save much grief and wasted effort later on
- Establish rigorous configuration & data management processes as early as possible – define the "data cascade"
- Don't trust your memory – write EVERYTHING down (agreements, definitions, information, etc.)
- It is extremely difficult (if not impossible) to separate estimating durations and making people-resource allocations – each has a bearing on the other
- Have the people doing the work involved in planning the work – they know more about it than anyone else
- Decide which TPM's you will use, on which tasks, and document them during the planning process
- Cost and schedule should tell the same story from different perspectives with the same ending

LESSONS LEARNED (2 of 3)

- Cost and schedule inputs are related – some are serial (such as resource use), some are parallel (resource & indirect rates)
- It always takes more than you think (money, time, & resources) – unproductive costs are a reality, be prepared
- Indirect costs are real and may double (or more) the total cost of your project – be prepared for this reality
- Schedule, cost, and technical risks are related – but are not necessarily always directly proportional
- Historical data is very valuable – USE IT! – chances are, someone else paid very dearly for it
- When using historical data, ensure you understand its context, especially in relation to your own

LESSONS LEARNED (3 of 3)

- *There is no such thing as a project too large or too small to benefit from good integrated project management practices – the best practices are those that are consistent in ideology but scalable in practice (i.e. they can shrink or grow to fit the circumstances)*